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"EFFECT OF VIBRATION ON MECHANICAL PROPERTIES OF A356 ALUMINUM ALLOY CASTING"

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ABSTRACT

The experimental investigation on the effect of mechanical vibration parameter (frequency and amplitude) on microstructure and mechanical properties of A356 aluminum alloy casting have been carried out. Mechanical vibrations were applied to A356 aluminum alloy in the frequency and amplitude range of 0 Hz-400Hz and 0-15 µm respectively . The effect of frequency of vibration on grain refinement and mechanical properties was investigated. The molten alloy filled mould was kept on the vibrating platform which vibrates in the frequency and amplitude range of 0 Hz-400Hz and 0-15 µm respectively. Vibrating table is coupled with vibration exciter . Mould is properly clamped on the table. Casting is prepared under stationary and vibrating conditions. Test specimens for stationary and vibratory casting were prepared for tensile test and microstructure examination. Tensile test of stationary and vibratory prepared specimens was conducted. It was observed that tensile strength ,yield strength and percentage elongation were improved by 26.8%, 17.7% and 52% respectively as compared to that of stationary prepared specimens. Improvement in the properties is attributed to grain refinement of vibratory prepared casting which evident from microstructure photograph.

KEYWORDS: Mechanical Vibration, Microstructure, SEM, Grain Refinement

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Original Article

INTRODUCTION

Solidification rate of any metallic casting depend upon two factors, cooling rate and melt temperature. These factors are responsible for formation of structure and the quality of any casting. A lot of research has been done under conditions of oscillations during solidification of a metallic alloy. This is done to increase the solidification rate and cooling rate of casting.

W. Wang et al.[1] , studied about the crystal nucleation and detachment from a chilling metal surface with vibration. A chilling molten metal is an effective way to produce lots of nuclei for forming equiaxed grains. To obtain finer equiaxed grains, it is necessary to increase synchronously vibration frequency as well as amplitude.

N. Abu-Dheir et al.[2] studied about the silicon morphology modification in the eutectic Al–Si alloy under mechanical mold vibration. The microstructure responsible is where the lamellar spacing tends to reduce and silicon morphology becomes fibrous with the increasing of the vibration amplitude as compared to gravity casting. However, it is also reported that by exceeding a critical value of vibration amplitude, the silicon tends to coarsen.

S. Guo et al.,[3]observed the microstructural refinement of DC cast AZ80 Mg billets by low frequency electromagnetic vibration and the experimental results show that the grains have been greatly refined by applying

electromagnetic vibration. The grains over the cross section of the billet tend to become homogenous under certain electromagnetic vibration conditions.

F. Wang et al.,[4]studied the changes of solidification parameters and the temperature profiles for the liquid in front of the solid–liquid interface caused by vibration. Uniform and fine-grained casting was obtained.

V. S Mudakappanavar et al.,[5] observed the vibration successfully broke the dendritic structure into small islands of Aluminum. Inducing vibration also resulted in fragmentation of silicon needles and uniform distribution of silicon flakes resulting in improved properties.

C. Vives and J. Cryst.[6]Observed the effect of the vibration which mainly originates inside the electromagnetic skin depth area and owing to the medium elasticity, is propagated throughout the melt and experimentally find as the magnetic-field strength and amplitude of the vibrating electromagnetic pressure is very small and so cavitation effects are also small.

R.J. Kissling et al. [7] reported to the vibration of a Copper Alloy (Cu-32Zn-2Pb-1Sn) improved yield and tensile strengths by about 15%, with a 10% reduction in grain size from the unvibrated state. In general, the α copper-zinc alloys (<35% Zn) exhibit grain size reduction and greater improvement in properties, while the α-β alloys do not.

G. Chirita et al.[8] compared the influence of vibration on the solidification behavior and tensile properties of an Al–18 wt%Si alloy at fixed amplitude and different frequencies with gravity castings without vibration and found the tensile strength was improved for low vibration frequencies but decreased for high frequencies.

F. Taghavi et al.,[9]studied grain refinement and density of A356 aluminum alloy under prolonged mechanical vibration and found the mechanical vibration tend to increase in grain refinement and density of A356 aluminum alloy, Maximum achieved grain refinement was 53% in 50 Hz and15 min .

Chworinov, N. [10] and Dmitrovich, A. M. et al.[11] reported as the vibration too is well known as a method of structural refinement. Its beneficial influence on the structure and properties of cast aluminium and copper alloys, a reduction in graphite flake size in cast irons was also reported.

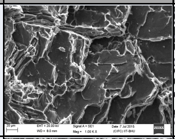
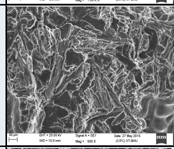
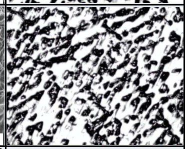
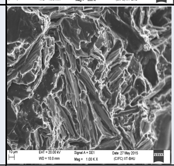
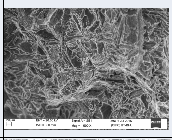
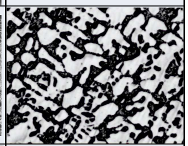
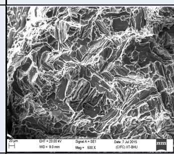
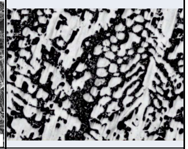
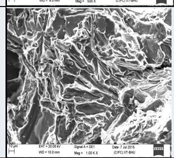
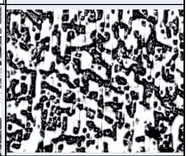
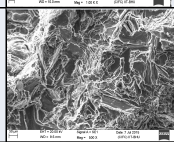
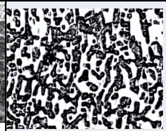
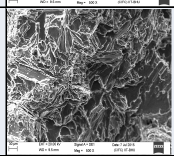
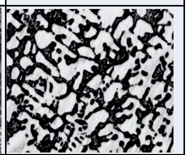
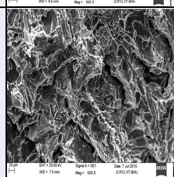
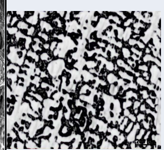
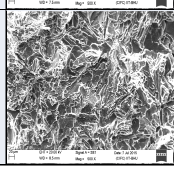
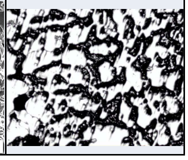
Experimental Procedure

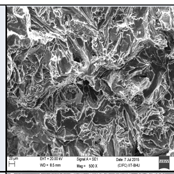
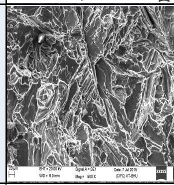
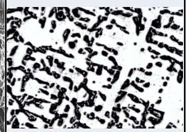
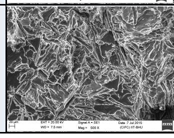
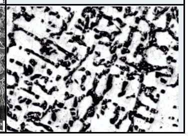
The A356 Aluminum alloys melted in a graphite crucible in pit furnace. As soon as the molten metal reaches approximate temperature of 750°C, it is taken out and degassed using the required quantity of degassing powder of Hexa Chloro Ethane in order to remove the dissolved hydrogen gas. Aluminium alloys will absorb or dissolve harmful quantities of hydrogen from atmosphere during melting and pouring. If the molten metal reaches the approximate pouring temperature (700°C), subsequent cooling and solidification will result in gas evolution, pinholes, and microscopic gas porosity. So degassing is performed to minimize these defects. The presence of oxides and coal ash in the surface of the molten metal are skimmed. Then the molten metal is poured into the mould cavity at a temperature of 700°C.

The developed experimental setup consists of two hollow rectangular base plate and oscillatory table made of mild steel plates, circular protector and screw jack. Oscillatory table rest on two shafts which are mounted on four bearings fixed over the base plate. During the solidification of casting mold were oscillated at different frequencies (0 Hz,100 Hz,200Hz 300Hz and 400Hz) and amplitudes (0,5,10,15 μm) of vibration with the help of an oscillator/ power amplifier and vibrator exciter. The mild steel mold was directly placed on oscillatory table and was hold by C-Clamps. The vibration

conditions such as frequency and amplitude could be easily controlled by oscillator/ power amplifier and vibrator exciter. The vibration conditions used during solidifications of castings and result obtained are given in Table 1.

Table 1: The Vibration Conditions Used for Experiment Mechanical Properties Obtain from Casting Sample

Frequency	Amplitude	UTS(MPa)	YS(MPa)	Elongation (%)	Toughness (Jule)	Hardness (HV) at Load 25 Gf for 30Sec	SEM of Tensile Fracture	Optical Microstructure (50X)
0	0	158	115.6	3.6	2.5	60		
100	5	177.5	127.4	4.5	3	66.7		
200	5	182.6	135.4	4.8	4.5	72		
300	5	200.5	138.7	5.5	6.5	79		
400	5	216.08	140.5	7.5	8	85.8		
100	10	174.5	125.5	4.2	3.5	69.8		
200	10	176.4	130.5	4.35	3	72.5		
300	10	188.6	132.5	5.8	5.5	75.5		
400	10	208.47	136.8	6.5	6.5	81.9		
100	15	165.2	122.4	3.78	4.5	65.6		

200	15	180.1	125.4	4.58	3	70.1		
300	15	186.3	128.6	5	4.5	74.1		
400	15	196.2	130.5	5.8	6	79.3		

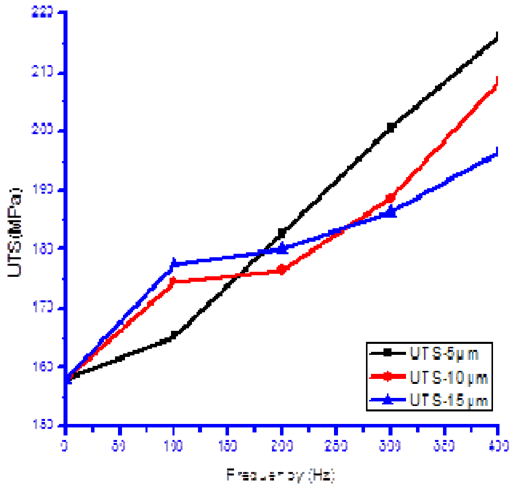


Figure 1: Effect of Frequency on Ultimate Tensile Strength

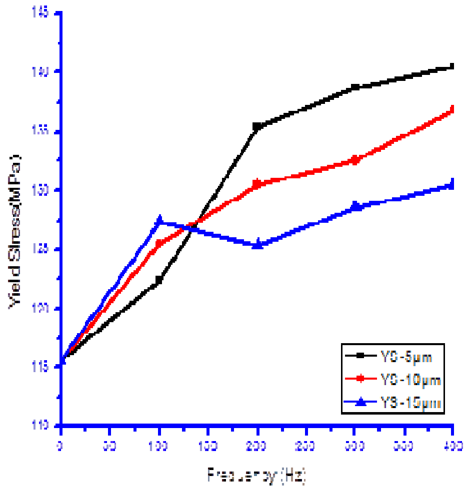


Figure 2: Effect of Frequency on Yield Strength

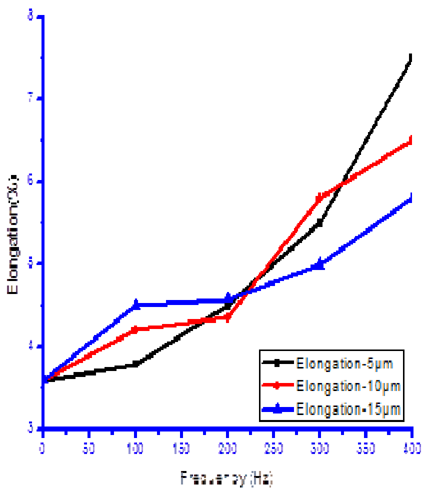


Figure 3: Effect of Frequency on % Elongation

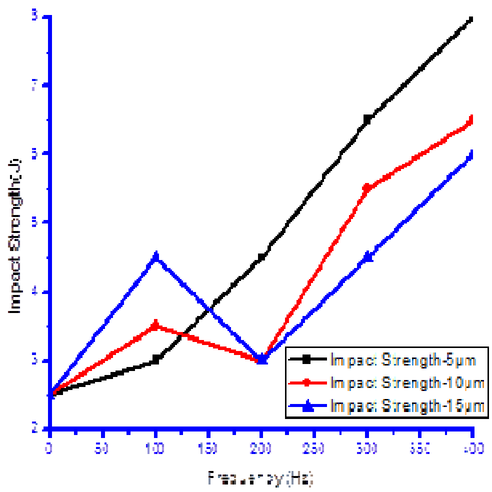


Figure 4: Effect of Frequency on Impact Strength

RESULTS AND DISCUSSIONS

A356 aluminum alloy casting were made without vibration to compare the results of castings with vibration. Mechanical vibration can collapse dendrite arms during solidification and disperse them in the melt. Dispersed broken dendrite arms act as nuclei in the melt and produce finer grains and microstructure. Vibration led to the breakage of dendrite arms and dispersed them in the melt. The experimental results showed significantly grain refinement and significant improvement in Tensile strength, Yield Strength, Elongation and toughness of castings with mechanical mold vibration during solidification as compare to casting prepared without vibration.

The optical microstructure and SEM tensile fractograph obtained with A356 cast alloys under stationary and vibrated conditions are shown in table-1. The effect of frequency of vibration on grain refinement and mechanical properties was investigated. The results pertain to the casting of A356 aluminum alloy at different vibrational frequencies. With the increase of vibration frequency, large needle-like silicon particle morphology transformed into fibrous small rod-like silicon morphology which is evenly dispersed in the grain boundary.

The fractured surfaces of A356 aluminum alloy shown in the table no1 obtained from the conventionally cast and vibratory casting showed a clear brittle fracture nature as a transgranular fracture mode due to its coarse microstructure in conventional cast specimen While the fractographs of A356 aluminum alloy obtained with the vibration method exhibited the obvious morphologies of the dimple fracture as an intergranular fracture mode because of a significant improvement in microstructure. Fractrography consists of dimples as well as flat surface which is indication that the tensile specimen failed in a quasi-cleavage .

CONCLUSIONS

Experimental Results obtained during the course of investigations are-

- Mechanical properties i.e. ultimate tensile strength, yield strength and elongation were improved by 26.8%, 17.7% and 52% respectively as compared with stationary solidified casting.
- The acicular eutectic silicon observed in A356 alloy can be improved from acicular to fibrous with the increase in frequency of vibration during the solidification.
- The SEM fractrography consists of dimples as well as flat surface which is indication that the tensile specimen failed in a quasi-cleavage i.e. mixed fracture.
- The experimental results showed significant grain refinement and remarkably improvement in hardness of castings with mechanical mould vibration during solidification.

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